CPP 6: French-German Session: Membranes and Porous Materials II

Time: Monday 11:15–12:45 Location: ZEU/LICH

Invited Talk CPP 6.1 Mon 11:15 ZEU/LICH

Hierarchical Porosity Meets Nanoconfined Water: Toward Water-Driven Functional Materials — •Patrick Huber — Hamburg University of Technology — Deutsches Elektronen-Synchrotron DESY

Natural materials achieve remarkable functionality using only simple chemical building blocks, relying on architectures that span multiple length scales. A key feature of many biological systems is their hierarchical porosity, which guides fluid transport from large channels down to nanopores where water acts as a nanoscale working fluid. In such confined spaces, water displays distinct structural dynamics and interfacial behaviour that strongly influence mechanical, transport, and optical responses. This contribution introduces a new class of sustainable water-driven materials whose active behaviour originates from the interplay between hierarchically porous solid networks and interfacial or nanoconfined water. These Blue Materials exploit water-mediated processes such as humidity-responsive actuation, capillary-driven transport, and pore-structure controlled optical effects. Their functionality is rooted in the precise design of their pore architecture, especially at the nanoscale where confined water governs dynamic material behaviour. Beyond emulating natural processes, these principles open pathways for harvesting electrical energy from environmental wetting-drying cycles, offering a sustainable approach to energy generation in porous materials.

CPP 6.2 Mon 11:45 ZEU/LICH

Accessing topological properties of mesoporous materials via SDGW model — •Georgiy Baroncha[1], Rustem Valiullin[1], and Eustathios Kikkinides[2] — [1]Felix Bloch Insitute for Solid State Physics, Leipzig University, Leipzig, Germany — [2]Department of Chemical Engineering, Aristotle University of Thessaloniki, Thessaloniki, Greece

Gas sorption is commonly used to characterize mesoporous materials, but its ability to reveal how pores are interconnected remains limited due to an incomplete understanding of network effects on phase behavior. In this work, we represent mesoporous structures using statistically disordered Bethe, and apply a statistical-thermodynamic approach to interpret adsorption/desorption or melting/freezing phase transitions. We demonstrate that gas sorption analysis can be used not only to determine pore size distributions, but also to quantitatively infer the average interpore connectivity and correlations between pore diameters in the material. At the same time, we find that sorption isotherms are largely unaffected by other aspects of pore network topology. These results identify the key structural factors shaping sorption behavior and broaden the capabilities of gas sorption for simultaneous assessment of pore size distribution and mean connectivity in mesoporous materials.

CPP 6.3 Mon 12:00 ZEU/LICH

2D Water in Clay Nanoconfinement: Tiny Space for Large Implications — •Vasily Artemov — Hamburg University of Technology

This talk presents recent advances in understanding the behavior of two-dimensional water in clay nanoconfinement, with a focus on its dielectric properties. Although clays are abundant, their crystal particles typically lack directional alignment. I will discuss an approach for self-assembling clay particles into large, scalable membranes in which the flakes are oriented parallel to each other, enabling a controlled and reproducible platform for studies of confined water at the nanoscale. Using this self-assembled nanofluidic platform, I will present experimental evidence of confinement-induced charge-separation effects that support electricity storage in water channels of 1 nm wide [1]. By combining insights from nanoscale physics, electrochemistry, and materials science, I will highlight how confinement within clay interlayers can influence ion transport, energy-storage phenomena, and our broader understanding of water at the interfaces.

[1] V. Artemov, S. Babiy, Y. Teng, J. Ma, A. Ryzhov, T.-H. Chen, L. Navratilova, V. Boureau, P. Schouwink, M. Liseanskaia, P. Huber, F. Brushett, L. Laloui, G. Tagliabue, A. Radenovic, Bulk electricity storage in 1-nm water channels, arXiv:2410.11983 (2024)

CPP 6.4 Mon 12:15 ZEU/LICH

Two coexisting populations of sorbed DMSO drive distinct structural changes in a swelling porous material — Raimund Teubler[1,3], Alexandra Serebrennikova[1,2,3], Maximilian Fuchs[1,3], Eduardo Machado Charry[1], Robert Saf[1], Erich Leitner[1,3], and •Karin Zojer[1,3] — [1]Graz University of Technology, Graz, Austria — [2]Wood Kplus Competence Center, Linz, Austria — [3]CDL for mass transport through paper, Graz, Austria

Understanding the swelling of cellulose-lignin-based fibers is essential for describing the mechanisms governing water and volatile uptake in porous materials such as paper. We reveal the dynamics of dimethyl sulfoxide (DMSO) uptake and quantify the resulting changes in fiber and sheet structure by combining three recently developed techniques based on concentration determination in coupled uptake/release experiments, microcomputed tomography (μ-CT), and optical microscopy. DMSO interacts with the fibers in a manner similar to water. We show that DMSO is incorporated into the paper sheet in two distinct populations, each contributing differently to the structural evolution of the material. The first population consists of DMSO molecules incorporated into the fibers, leading to fiber swelling. The second population accumulates at the fiber surfaces; although these molecules bind to and are released from the surface rapidly, they gradually modify the fiber surface [1]. As a consequence, built-in stresses within the fiber network are released, causing structural changes that persist long after fiber swelling has ceased.

[1] R. Teubler et al., DOI: 10.1007/s10450-025-00656-x.

CPP 6.5 Mon 12:30 ZEU/LICH

Electrochemical control of photoluminescence emission by a porous silicon membrane — •Manuel Brinker[1] and Patrick Huber[1,2] — [1]Institute for Materials and X-ray Physics, Hamburg University of Technology, Denickestr. 15, Hamburg 21073, Germany — [2]Centre for X-ray and Nano Science CXNS, Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, Hamburg 22607, Germany

Porous silicon is a highly versatile porous material with a broad range of exceptional properties. Due to the geometrical confinement of the pore walls, the band structure is strongly altered and the pore walls effectively act as quantum wires. Thus, photons are emitted in the visible range when the membrane is excited by a UV source. This optical effect has been widely researched and is the foundation for porous silicon to be applied, e.g., as a sensor material in the life sciences. Here, we study the influence of electrochemo-mechanical coupling on the photoluminescence performance. Thereby, charge carriers are accumulated in the electric double layer of a porous silicon electrode by charging it in an electrolyte solution. A change in surface stress at the interface with the porous material is induced and results in an overall mechanical reaction of the porous material. The strain acting on the pore walls consecutively influences the emission characteristics of the photoluminescence emission. An extensive in-situ study ascertains a highly linear dependence of the emission peak's wavelength on the charging state of the electrode. This research establishes the groundwork for porous silicon electrodes to be utilized as mechano-optical sensors.